Distribution of Sagebrush as Related to Site Differences in Albany County, Wyoming[1]

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Among plants commonly called sagebrushes are many species and growth forms which together populate a substantial portion of the rangelands of the western United States. Sagebrush characterizes the landscape in the Great Basin and in some adjacent areas. Much has been written and said about the soils on which sagebrush grows, but too little attention has been given to the distribution of specific species and forms as related to different kinds of land and land uses.

Reference often is made to sagebrush as an indicator of soil suitable for cultivation. Also, much has been written about sagebrush control for range improvement. Yet sagebrush occurs in many species and forms with different roles on many sites having substantial differences in soil properties. Many such sites obviously are unsuitable for cultivation, and sagebrush control for grazing use cannot be a blanket prescription.

A major purpose of this study was to determine if differences in species and growth forms in Albany County, Wyoming, could be related to differences in soil characteristics such as depth, texture, permeability, alkalinity, salinity, and wetness. Other characteristics considered were parent or underlying material of the soil, topographical position, and climatic belts as they might influence the species of sagebrush adapted to the site.

Four species of sagebrush were recognized in this study, namely, big sagebrush *(Artemisia tridentata)*, silver sagebrush *(Artemisia cana)*, black sagebrush *(Artemisia nova)*, and threetip sagebrush *(Artemisia tripartita)*. Scientific, authority, and common names of all plant species to be mentioned are included in an appendix.

Problems and Literature

Any ecological study of sagebrush and its distribution leads promptly to two classes of problems. The first results from complexities in the taxonomy of the genus *Artemisia*. The second results from the difficulty of differentiating increase and invasion from normal occurrence in various types of sites.

The taxonomy of the genus received intensive study by Rydberg (1913), Hall and Clements (1923), and Ward (1953). Recent research in Colorado (Langenheim, 1956), describing the occurrence of sagebrush, stated ". . . *Artemisia tridentata*, includes an assemblage of heteroploids adapted to different combinations of arid environmental conditions . . . hybridization of *A. tridentata* with *A. cana* and *A. spiciformis* of nearby areas further complicates the systematics . . . the individuals in the area can only be considered part of the *Artemisia tridentata* complex, although in all probability they represent a race that is physiologically distinct from others in western North America." Hence, it is evident that limited knowledge of the systematics within the genus place limitations on application of ecological findings related to named species of sagebrush.

The occurrence of sagebrush in relation to factors resident in soils has received much study. Among the first reports is one by Kearney, *et al.* (1914) stating: "In the Tooele Valley sagebrush

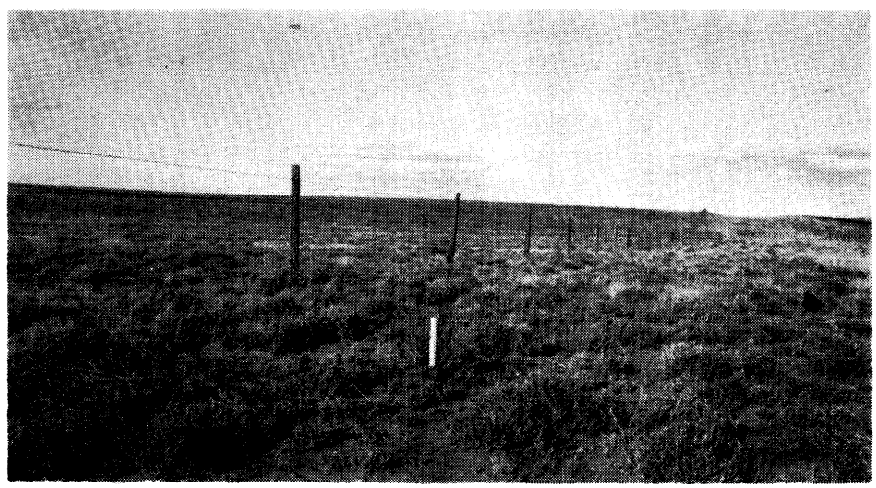

FIGURE 1. Big sagebrush growing in an upland position with a predominance of western wheatgrass and lesser amounts of needle-and-thread, Sandberg bluegrass, and prairie Junegrass. The soil is a deep silty clay loam, which is slowly permeable. The reaction is slightly alkaline, and the soil has only a small amount of soluble salts.

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occurs chiefly on the bench lands which skirt the mountains. In some parts of the valley, especially where the soil is sandy, the plants of sagebrush are tall, vigorous and stand close together. In other and more extensive areas, where the moisture conditions are less favorable, they are scattered and stunted, and the proportion of new growth to old is small."

Quite recently, Gates (1956) in a study of the salt-desert ranges of Utah found that edaphic factors were of primary importance on the distribution of the shrub types—sagebrush, winterfat, shadscale, Nuttall's saltbush, and greasewood. He found Nuttall's saltbush, greasewood, and shadscale growing on soils with the highest salt content, an average of 0.89, 0.83, and 0.53 percent, respectively. Sagebrush and winterfat were found on soils with an average salt content of 0.32 and 0.36 percent, respectively. The five types varied significantly from each other in amount of soluble sodium, 719 parts-per-million for sagebrush to 2,215 ppm for Nuttall's saltbush. All species had a relatively wide range for each of the significant soil factors. The wide range of tolerance of the species studied for edaphic factors suggested the presence of ecotypic variation.

In the many references perused, that reported relations between occurrence of sagebrush and soil factors, there was inadequate evidence to determine the degree to which the observed occurrence was related to grazing influences which might have altered the effects of edaphic and climatic influence. That such influences may be great is evident from an investigation by Cooper (1953).

Description of the Study Area

This study deals with the occurrence of four species of sagebrush in Albany County, Wyoming, between the elevation of 6,000 feet and 9,500 feet.

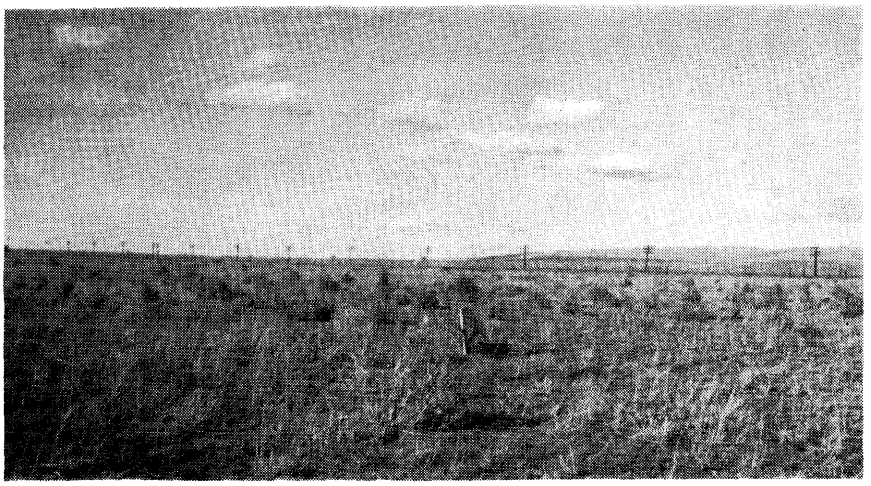

FIGURE 2. Silver sagebrush growing in an upland position. The major associated species are needle-and-thread, blue grama, western wheatgrass, needleleaf sedge, and Hood's phlox. The soil is deep with a fine sandy loam topsoil underlain by sandy clay loam with prismatic structure. The reaction is nearly neutral with only a slight amount of soluble salts.

Topographically the Laramie Plains portion of Albany County is a nearly level basin which is dissected by three major streams, namely, the Big Laramie River, Little Laramie River, and the North Laramie River. These three major drainages have numerous tributaries. The drainages originate from the higher mountainous areas which form a crescent on the north, east, and south sides of the basin. The mountainous area is pre-Cambrian, granitic material that is flanked on the basin side by the older sandstones and limestones of the Pennsylvania and Mississippian ages, locally called the Casper formation. The floor of the basin is largely composed of Cretaceous age materials that have in some cases been covered over by river terraces and outwash alluvial deposits from the adjacent mountain areas. Along the southwest side of the study area there is another large area that is geologically of the Eocene age and locally called the Wind River and Hanna formations.

Records of the United States Weather Bureau, near the City of Laramie, during the past sixty years, reflect climatic conditions for the lower elevations. Precipitation belts within the county, to be referred to later, were determined from isohyetal maps of the same agency. Average annual precipitation at Laramie is 11.19 inches but has varied during the sixty-year period from 3.75 to 15.07. Over 60 percent of the precipitation occurs between April 1 and September 1. Much of the moisture comes in the form of snow during the months of March and April. Only seven times in the last 60 years has the temperature of the area risen above 90° F. A low temperature of 42° below zero has been recorded. The sky is clear most of the time, the relative humidity is low, and the wind reaches an average velocity in March of 14 miles per hour. The plains area of Albany County has an average of 106 frost-free days. The frost-free period has varied from 71 to 152 days over the 60-year period.

In various parts of the county, areas may be found that are characterized by dominance of one of the species of sagebrush (Figures 1, 2, 3, and 4).

Method of Study

To determine site preferences of sagebrushes within the study area, sites were selected at random to include an adequate sam-

ple of each of the four distinct species. Consideration was given to an adequate range in soils, relative positions, parent materials, and rainfall belts. This resulted in selecting 51 different sites located throughout the area. The final tabulation showed big sagebrush occurred on 17 sites, silver sagebrush occurred on 14 sites, black sagebrush occurred on 12 sites, and threetip sagebrush occurred on 11 sites.

Each site was studied by selecting an area on which a particular species occurred, and within it marking off a circle ten feet in diameter from a center selected at random. This size circle was used because it was large enough to give a good cross-section of the herbaceous vegetation and yet was small enough to permit accurate counting of sagebrush individuals. After perennial herbaceous species were recorded, and plants of each sagebrush species were counted, the latter were measured to determine the range in height. Seedlings were not included in the height measurements because the roots would not have penetrated the full soil depth, and hence the plants would not accurately reflect soil conditions.

The soils were excavated to determine soil depth and the type of underlying material. Where the soil was more than 48 inches deep, the underlying material was deduced from a study of the surrounding area. Characteristics of the soil recorded were: soil depth, topsoil texture, subsoil permeability (based on texture and structural indications), parent or underlying material, wetness, salinity, and reaction. The reaction was determined by the use of the organic indicators phenol red, bromthymol blue, and thymol blue. Other recorded characteristics and information about the site included: relative position of the site, the direction of the slope or exposure, percentage slope, precipitation belt, date of study, and the legal description to the nearest section.

Results

Results of the investigation are reported in Tables 1 and 2, and discussed by species in the following sections.

Big Sagebrush

Big sagebrush was examined on 17 sites distributed throughout the study area. The depth of soil to which its roots could freely penetrate was found to be at least 15 inches in all cases. It was found on only two sites where the soil depth was less than 36 inches deep. Evidently, it can become a dominant member of a plant association only where soils are at least moderately deep. When this species appeared to be growing on a very shallow soil, closer examination showed plants were growing in deeper soil pockets or that the substratum was jointed to allow deep penetration of the roots.

Of the 17 sites, 3 had sandy loam topsoils, 10 had loamy topsoils, and 4 had clayey topsoils. None had extremely heavy or very sandy topsoils.

All of the sites studied were free of effects of high water tables, and there were no indications that the soils had ever been influenced by such a condition. There were no visual evidences that soluble salt content of the soils was high or even moderately high. Visual evidences used were accumulations of salt crystals, whiteness of the surface, and the presence of salt tolerant plants in the community.

It was found that big sagebrush grew on soils with a wide range of subsoil permeabilities. Indications were that wherever permeability greatly restricted

Table 1. The distribution of four species of sagebrush as related to soil factors, Albany County, Wyoming.

Species	Soil Depth	Topsoil Texture	Subsoil Permeability	Underlying Material	Reaction	Wetness	Salinity
Big sagebrush (*Artemisia tridentata*)	14* deep 2 moderately deep 1 shallow	3 sandy 10 loamy 4 clayey	1 slowly permeable 16 moderately permeable	6 shale 3 sandstone 4 granitic 4 gravel	12 slightly alkaline 5 neutral	all dry	little, if any
Silver sagebrush (*Artemisia cana*)	9 deep 3 moderately deep 2 shallow	7 sandy 7 loamy	11 moderately permeable 3 rapidly permeable	4 sandstone 10 gravel	11 slightly alkaline 3 neutral	3 slightly wet 11 dry	2 slightly saline 12 no salinity
Black sagebrush (*Artemisia nova*)	2 moderately deep 5 shallow 5 very shallow	1 sandy 11 loamy	7 moderately permeable 5 rapidly permeable	6 granitic 6 gravel	4 slightly alkaline 8 neutral	all dry	little, if any
Threetip sagebrush (*Artemisia tripartita*)	4 moderately deep 6 shallow 1 very shallow	2 sandy 9 loamy	9 moderately permeable 2 rapidly permeable	8 granitic 3 gravel	11 neutral	all dry	little, if any

* Number of sites on which the particular factor was present.

movement of air and water, big sagebrush reflected this condition by small stature. Plants ranged in height from 4 to 5 inches on sites where the subsoil was heavy textured with little or no fracturing of the soil mass, to 42 inches on sites where the soil was deep silt loam with a granular topsoil, a well fractured prismatic-structured subsoil, and underlain by fractured granitic bedrock. Permeability data indicated that this soil factor had little influence on distribution of the species but much influence on the size of the individuals. The lower the soil permeability, the smaller the individuals.

Big sagebrush occurred on all classifications of parent materials, namely, sandstones, shales, limestones, granites, terraces, and alluvial gravels. However, there are large areas near the center of the Laramie Plains where it is absent. Geological maps show this area to be underlain by a Cretaceous bedrock, usually highly saline or alkaline. Reaction of soil profiles where big sagebrush occurred ranged from pH 6.6 to 8.5, showing slight tolerance to alkalinity but not occurring on highly alkaline soils.

Topographic position in relation to the surrounding terrain was correlated with differences in plant communities. Some species respond favorably and flourish from additional moisture in lowland positions while others do not, and either die or do not become established in lowland communities. Big sagebrush is predominantly an upland species in this area. On the four sites where it occurred on a lowland position, the slopes were in excess of 4 percent, permitting little if any ponding of water on the surface.

Exposure is often closely correlated with amount of forage produced and composition of plant communities, but big sagebrush was found on all major exposures in this area. With close examination seemingly anomalous distributions could be explained by differences in soil properties.

Silver Sagebrush

Silver sagebrush was studied on 14 sites distributed throughout the study area. It was found to be growing largely on soils which were in excess of 20 inches deep. Nine of the 14 sites had soil depths in excess of 36 inches and only two sites had soil depths less than 20 inches. These data indicate that silver sagebrush requires deep to moderately deep soils in this area, but it will grow on shallow soils in some instances.

A study of the texture of the topsoil in these sites revealed that in upland position, in all cases, silver sagebrush occurred on sandy topsoils. It did not occur on soils with heavy textured topsoils, regardless of topographic position of the site. Nor did it occur on soils where subsoil permeability was less than moderate. Eleven of the 14 sites were moderately permeable, and three of the sites were rapidly permeable.

Silver sagebrush was found to occur on only two basic types of parent or underlying material, namely, sandstone and gravel. The reasons are not entirely clear, but, as noted, it does not grow on heavy textured or slowly permeable soil, and these properties seldom occur on the above-mentioned underlying materials. Eleven of the sites were moderately alkaline with pH between 7.4 and 8.5. Three of the sites had a pH of between 6.6 and 7.3.

Silver sagebrush was the only one of the four species studied that grew on soils influenced by a high water table. Three of its 14 sites had water tables within the zone of root penetration. This need not indicate that it prefers high water tables, but does indicate that it will tolerate some high water table. Two of the soils upon which it grew had indications of being affected by an accumulation of soluble salts. The salt content was not great and could only be classified as slightly saline. This saline condition, in both cases, was associated with a high water table.

One of the most distinctive features in the distribution of silver sagebrush was its occurrence on lowlands. Of the 14 sites, 10 were lowland sites and only 4 were upland sites. This species seemed adapted, in this area, to sites

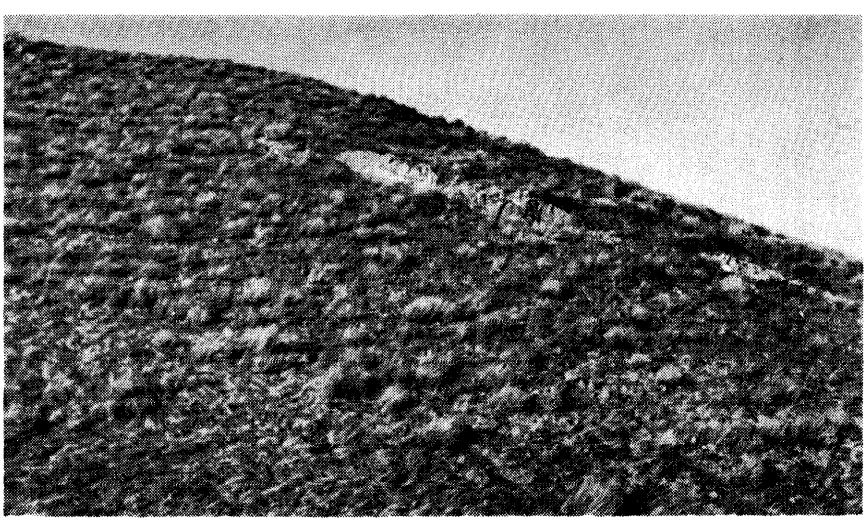

FIGURE 3. Black sagebrush growing on steep slope with very shallow soil underlain by granitic bedrock which is more or less free from fractures. Bluebunch wheatgrass was the predominant associated species with lesser amounts of prairie Junegrass, Sandberg bluegrass, needle-and-thread, and Indian ricegrass.

receiving more moisture than normal for the climate. It did not occur on slopes greater than 4 percent and 9 of the 14 sites were nearly level. Data indicated that exposure did not influence distribution. Plant height ranged from 7 to 40 inches. The smaller plants, or those ranging from 7 to 18 inches, were largely found in the upland sites. Data showed that the more water available for plant growth, the taller were the individuals. Twelve of the sites studied occurred in the belt of 10 to 14 inches of average annual precipitation, while two sites were in the 15- to 19-inch belt.

A study of the association of silver sagebrush with other perennial vegetation showed only one major distinction between this species and the other three. It was the only one of the four species of sagebrush that was found to be growing in the same plant association with basin wildrye *(Elymus cinereus)*. This distinction applied to lowland sites, since basin wildrye did not occur in the upland position with sagebrush.

Black Sagebrush

Black sagebrush was studied on 12 sites in widely separated locations throughout the study area. The soils on which it grew were generally shallow to very shallow. Five sites were very shallow, 5 were shallow, and only 2 were of medium depth (20-36 inches). The latter were gravelly throughout the profile and were underlain by gravel. The topsoil texture on all these sites ranged between sandy loam and gravelly silt loam. Topsoils of very sandy or very heavy texture seemed to exclude black sagebrush. Subsoil permeability characteristics of the sites where it occurred showed 7 were moderately permeable and 5 rapidly permeable. There was no instance where the subsoil was slowly or very slowly permeable.

The nature of the underlying or parent material of soil seemed highly significant. Black sagebrush was found only on soils underlain by gravel or granitic materials. It also was observed that where the underlying material was granitic bedrock and was distinctly fractured, big sagebrush replaced black sagebrush in the plant association.

Eight of the sites where black sagebrush grew had a reaction close to the neutral point, with pH between 6.6 and 7.3. The remaining four sites had soils that were slightly alkaline. None of the soils indicated the presence of even a moderate accumulation of soluble salts. All of the soils were extremely well drained, which would prevent soluble salts from accumulating in the soil profile. The species is adapted to steep slopes, and exposure of the slope did not materially affect distribution.

Black sagebrush ranged from 4 to 10 inches high. Eight of the sites studied occurred in the 10- to 14-inch precipitation belt and four of the sites in the 15- to 19-inch belt. Bluebunch wheatgrass *(Agropyron spicatum)* was the only plant that grew with black sagebrush that could be correlated as being distinctly adapted to the same site conditions. Both occurred on 7 of the 12 sites studied.

Threetip Sagebrush

Threetip sagebrush was studied on 11 sites distributed along the east and west sides of the study area. These areas are higher in elevation than the plains areas and the estimated average annual precipitation is between 15 and 19 inches.

The soil depth characteristics of the sites where threetip sagebrush occurred were as follows: four with depths of between 20 and 36 inches, six with depths of between 10 and 20 inches, and one site with depth of less than 10 inches. There were no cases where soil was over 36 inches deep. It was observed that

Table 2. Distribution and height of sagebrush species as related to factors other than those resident in soils.

Species	Relative Position	Exposure	Height of Sagebrush Plants**	Rainfall Belt	Grass Species Significantly Associated
Big sagebrush *(Artemisia tridentata)*	14* Upland 3 Lowland	All exposures	1 6" or less 8 6"-18" high 8 18"-42" high	11 10"-14" 6 15"-19"	None
Silver sagebrush *(Artemisia cana)*	4 Upland 10 Lowland	All exposures	0 6" or less 7 6"-20" 7 20"-40"	12 10"-14" 2 15"-19"	*Elymus cinereus*
Black sagebrush *(Artemisia nova)*	12 Upland	All exposures	5 6" or less 7 6" to 10" high	8 10"-14" 4 15"-19"	*Agropyron spicatum*
Threetip sagebrush *(Artemisia tripartita)*	7 Upland 4 Lowland	All exposures	All individuals less than 7" high	All 15"-19" belt	*Muhlenbergia filiculmis*

* Number of sites on which the particular factor was present.

** Based on measurement of all individuals in study plot to determine range in height.

deeper soils in the same general area were occupied by big sagebrush. Threetip sagebrush was confined to the sandy and loamy textural groups. Subsoil permeability was found to be very similar to the situations for silver and black sagebrushes. In no instance could the subsoil be rated slowly permeable (less than approximately 0.8 of an inch per hour). The underlying parent material of the soils supporting threetip sagebrush was limited to recent alluvial gravel and granitic bedrocks. The gravel was composed of granitic material, and in all cases there was recent outwash material from adjacent granitic mountains.

One of the outstanding characteristics of this species was that it was limited to soils with pH readings less than 7.3. Threetip sagebrush was not found on sites affected by high water table or by evident accumulation of soluble salts. In all cases the soils were well drained both internally and on the surface. It was not confined to the upland position. Seven of the sites where it occurred were in upland positions and 4 in lowland positions. The lowland positions were well drained, and the slopes of these areas exceeded two percent in all cases. With the exceptions of three sites, where it occurred in swales, the topography was rolling smooth slopes with very little exposure of granitic bedrock. Wherever bedrock outcropped and slopes became abrupt and steep, threetip sagebrush was not a member of the plant community. Causes, in terms of site factors, are not fully understood.

All individuals of threetip sagebrush were less than 7 inches tall on the sites studied. The species occurred entirely within the 15- to 19-inch precipitation belt. This situation could be the result of the plants requiring more precipitation than falls in the 10- to 14-inch belt, or it might be due to the fact that these higher rainfall areas are primarily granitic bedrock, and the plants are adapted to the soils formed from the granites.

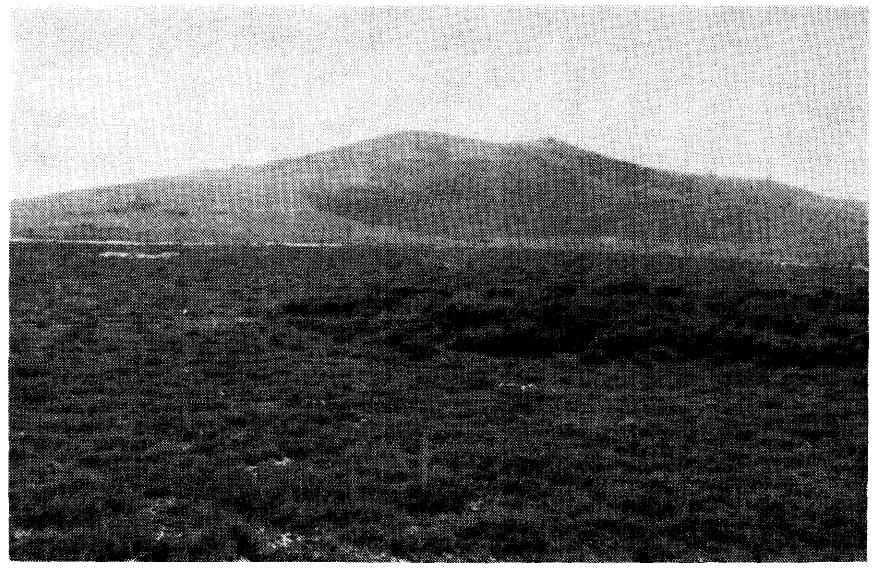

FIGURE 4. Threetip sagebrush growing in upland position in association with western wheatgrass, slimstem muhly, blue grama, and Sandberg bluegrass. The soil is a shallow (10"-20") granitic loam underlain by granitic bedrock. The area of taller sagebrush in right center of the figure is big sagebrush growing in a pocket of deeper soil.

The only correlation that could be made showing association with other perennial plants was with slimstem muhly (*Muhlenbergia filiculmis*). Slimstem muhly was not found associated with any of the other three sagebrush species studied.

Summary and Conclusions

Four species of sagebrush have ranges which include the area studied in Albany County, Wyoming. Local distribution of each species was associated with factors of the physical environment as follows:

1. Big sagebrush (*Artemisia tridentata*), of the four species studied, was found over the greatest variety of site conditions. Within this species there are different growth forms associated with differences in soil and water relationship of different types of sites. This was the only species that grew on soils with dense, heavy textured subsoils and on soils underlain by shale.

2. Silver sagebrush (*Artemisia cana*) was most often found on lowlands, but it also occurred in upland sites where topsoils were sandy and subsoils were at least moderately permeable to movement of water and air. This species was the only one of the four studied which grew where water tables occurred within the root zone. Soil mottling, indicating incomplete oxidation, was frequently evident in the root zone of this species. It did not occur on soils underlain by shale or granitic bedrock within the root zone.

3. Black sagebrush (*Artemisia nova*) was found only on the uplands, where it occurred on shallow and very shallow soils. The soil depth exceeded 20 inches in only two of the 12 sites studied. This species did not occur on soils underlain by shale or sandstone but instead on soils underlain by gravel or granitic bedrock.

4. Threetip sagebrush (*Artemisia tripartita*) was the only species which occurred entirely within the higher precipitation belt and higher elevations of the study area. It occurred only on soils underlain by granitic bed-

rock or gravel adjacent to and derived from the granites. It also was the only species restricted to soils where the reaction in all cases was less than pH 7.3.

Properties of the soil, its topographic position, the bedrock on which the soil lies, and climate interact to create distinctive physical environments that could be associated with the local distribution of the four species.

Heights of mature plants of big sagebrush and silver sagebrush were closely related to physical characteristics of the site.

The current distribution of sagebrushes in relation to factors of the physical environment was frequently observed in the process of being modified by close grazing. Changes in local distribution occur primarily through reduction of competition from herbaceous species through grazing. Local distribution undoubtedly has been affected more than outside limits of total range, but the extent of these modifications could not be determined.

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List of Plants

The following plants occurred on the sites studied: Indian ricegrass *(Oryzopsis hymenoides)*, big sagebrush *(Artemisia tridentata)*, threetip sagebrush *(Artemisia tripartita)*, black sagebrush *(Artemisia nova)*, silver sagebrush *(Artemisia cana)*, blue grama *(Bouteloua gracilis)*, western wheatgrass *(Agropyron smithii)*, bluebunch wheatgrass *(Agropyron spicatum)*, prairie Junegrass *(Koeleria cristata)*, slimstem muhly *(Muhlenbergia filiculmis)*, needle-and-thread *(Stipa comata)*, green needlegrass *(Stipa viridula)*, Sandberg bluegrass *(Poa secunda)*, Canby bluegrass *(Poa canbyi)*, basin wildrye *(Elymus cinereus)*, Idaho fescue *(Festuca idahoensis)*, mountain brome *(Bromus carinatus)*, needleleaf sedge *(Carex eleocharis)*, threadleaf sedge *(Carex filifolia)*, Hoods phlox *(Phlox hoodii)*, plains pricklypear *(Opuntia polyacantha)*.